Flexible Blades for Tidal Turbines

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Flexible Blades for Tidal Turbines

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1. Introduction:

Wave-current interactions and turbulence lead to cyclical load fluctuations on tidal turbine blades (Fig. 1), limiting their fatigue endurance. The current industrial trend is to develop stronger and more rigid structures capable of weathering these load variations. This poster presents an alternative approach: that of using flexible blades to increase the durability and survivability of tidal turbines.

The flexible blade camber passively morphs in response to the surrounding pressure field; effectively controlling the angle of attack (AoA) experienced. This reduces the likelihood of stall and minimises the load change caused by the wave-current interaction and turbulence.

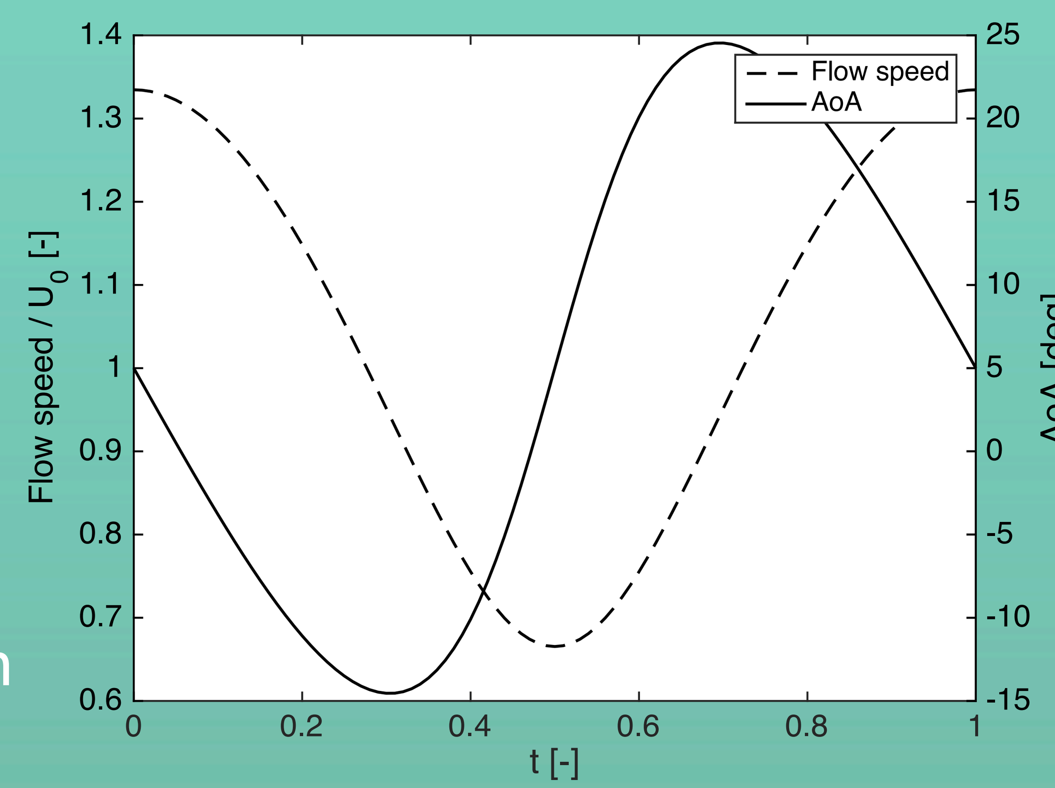

Fig. 1: Variation in flow speed and angle of attack caused by the wave-current interaction. Plotted over a single wave period at the depth of the 2D blade section.

2. Method:

Constant cross-section rigid and flexible blades, corresponding to the blade profile at 3/4th blade radius of a full, twisted turbine blade, are tested at fixed depth in Edinburgh's combined wave and current flume. Particle image velocimetry (PIV) and laser doppler velocimetry are used to gain an in-depth understanding of the incident flow field (Fig. 2); lift and drag are measured via a dual axis load cell and free surface elevation effects are monitored with wave gauges.

A loosely coupled fluid structure interaction code is developed combining linear wave and cantilever beam theories to predict the loading behaviour.

3.1 Rigid PIV Results

Both leading edge and trailing edge separation can be seen in Fig.2 (left) when AoA is large. This leads to larger load fluctuations through one wave period.

3.2 Flexible PIV Results

Flow remains attached through a wave period when the flexible blade was tested (Fig. 2, right), leading to reduced amplitude of the loading cycle.

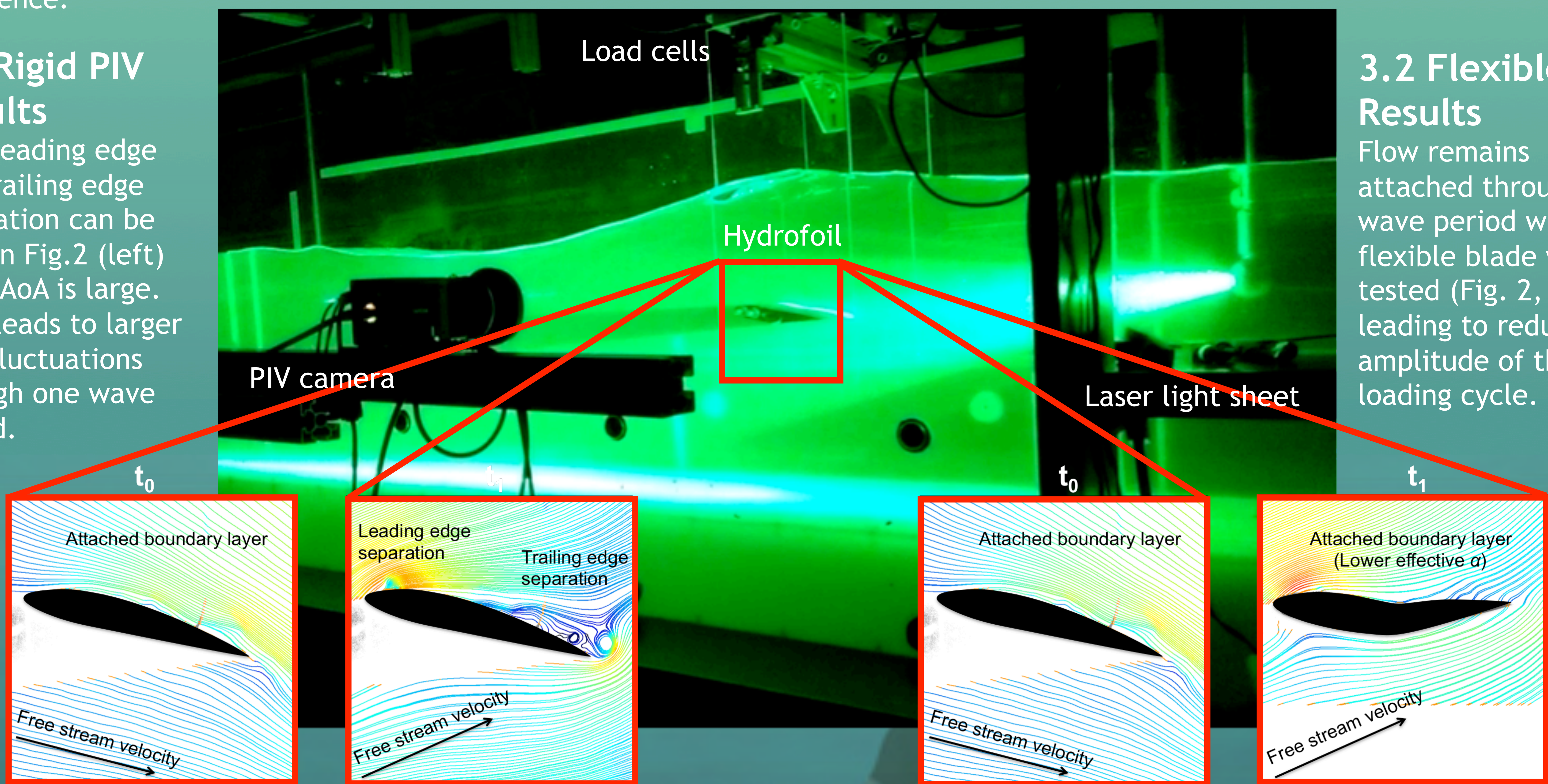

Fig. 2: PIV measured streamlines coloured by flow speed (red is high speed, blue is low speed) around a rigid (left) and flexible (right) tidal turbine blade in turbulent wave-induced oscillating current.

4. Comparison with Numerical Model

Modelling the loading of the flexible blade as a quasi-steady loading of a cantilever beam we can predict the loading behaviour under the flow conditions given in Fig.1. These results are shown for the fixed depth, constant cross-section blades in Fig. 3 with comparisons to the experimental results. As expected the amplitude of the load fluctuations is smaller for the flexible case whilst the mean forces remain approximately constant. This means that the flexible blade could be a viable option for reducing fatigue load effects whilst not having a large detrimental effect on the power generated.

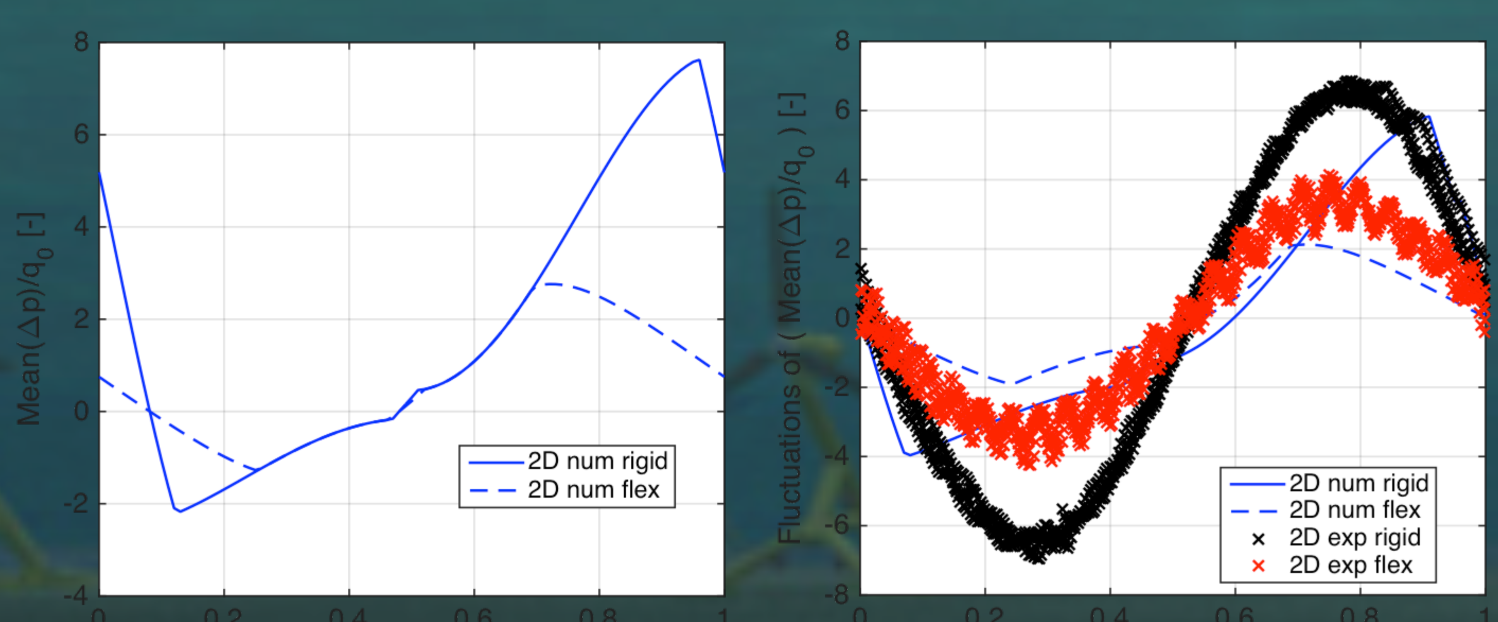

Fig.3: Comparison of the numerical and experimentally derived normal force coefficient for both the rigid and a flexible foil in 2D flow.

5. Future Work

On-going research focuses on the underlying mechanisms of dynamic stall for rigid and flexible tidal turbine blades in a wide range of onset flow conditions and blade flexibility; both in 2D (tested above) and 3D (rotating) conditions. The inclusion of rotational effects leads to increased frequency of AoA fluctuations as the turbine blade rotates through the depth varying wave field (Fig.4).

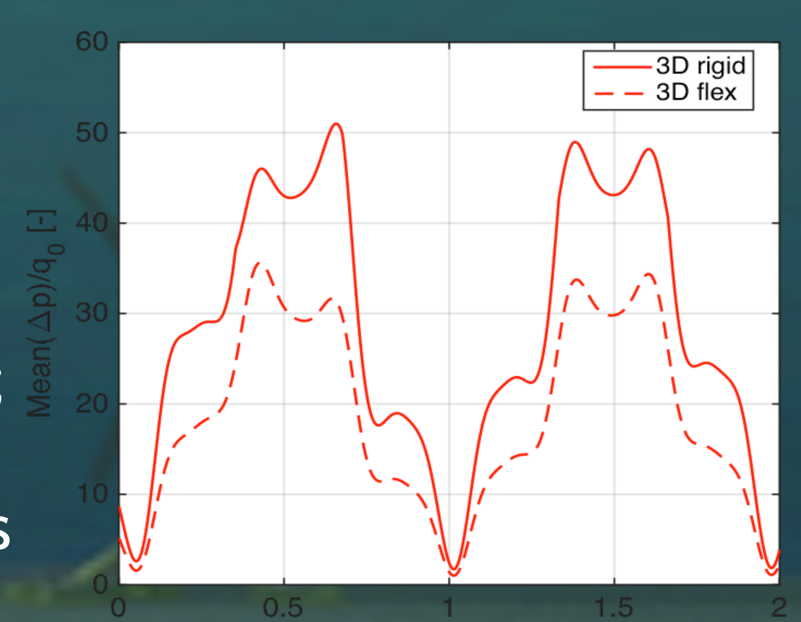

Fig.4: Computed normal force coefficient when turbine rotation is included.

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